CHAPTER 4

Reactions and the

Getting Ready...

- Why are coal, oil, and natural gas called "fossil fuels"?
- Name the type of reaction that gives off heat or light.
- What are some clues that a combustion reaction has occurred?
- What type of chemical reaction occurs when you mix vinegar and baking soda?

Science Log

List 10 chemical reactions that you encounter on a regular basis. Describe the role each reaction plays in your life. As you read this chapter, you will learn about some common chemical reactions that you may not normally notice.

What do these pictures have to do with the study of chemistry?

To answer, examine the photograph of the cars and trucks driving over the steel bridge. Chemistry has allowed us to harness the energy stored in oil, natural gas, and other fossil fuels to power our vehicles and industries.

Chemistry also plays an important role in the steel bridge. Chemical reactions are used to make the steel. Chemical reactions that form rust are also at work trying to weaken the structure.

Even something as natural as rain has a chemical connection. In some parts of Canada, pollution from combustion reactions has created acid deposition. The picture at the top left of page 59 shows a forest damaged in this way.

In this chapter, you will explore chemical reactions between acids and bases and learn how we use this knowledge to combat acid deposition.

You will also investigate how combustion reactions lead to global climate change and acid deposition, and you will demonstrate the environmental conditions that cause the corrosion of steel. In addition, you will identify technologies that protect steel against corrosion.

Environment

What You Will Learn

In this chapter you will learn:

- how to describe changes to reactants and products in fossil fuel combustion reactions
- how the products of fossil fuel combustion affect our environment
- how to explain common acid–base neutralization reactions
- how technologies can reduce the emissions that affect our environment
- how to describe changes to reactants and products in rusting reactions

Why It Is Important

- Some of the products and conveniences you enjoy can negatively affect the environment. What if you had to give up some of the conveniences you have come to depend on? Knowing more about chemical reactions helps you make choices that are good for you — and for the environment.

Skills You Will Use

In this chapter you will:

- plan investigations of questions, ideas, problems, and issues
- carry out procedures using a broad range of tools and techniques
- demonstrate a knowledge of WHMIS standards by handling chemicals and other materials properly
- compile, analyze, and display information in a variety of formats
- work as part of a team to address problems and communicate information

Starting Point ACTIVITY

The Halifax Explosion

An explosion in Halifax on December 6, 1917, was one of largest, most violent human-made, energy-releasing chemical reactions in history. This chemical reaction killed nearly 2000 people and injured about 9000 others. In this activity, you will do research to uncover the cause of the explosion.

What to Do

1. Read the Internet Connect below and follow the links to start your investigation.
2. Present your findings in a series of diagrams or a flowchart that shows the disaster as a sequence of events. Include captions or brief descriptions about what happened at different points during the disaster.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

Use the Internet to investigate the cause, the chemistry, and the consequences of the Halifax explosion. Go to the above web site, then to Internet Connects, Unit A, Chapter 4, and then to The Halifax Explosion.

What Did You Discover?

1. Do the analysis provided by your teacher.

4.1 Fossil Fuel Combustion

Figure 4.1 Fossil fuels provide the energy to power cars, and provide heat to appliances such as this gas stove burner.

How many of the following things do you do each day?

- switch on a light bulb or use an electric hair dryer
- drive a car or get a ride on a bus
- heat your home with a natural gas furnace
- use natural gas to heat the water for your shower or bath

READING Check

Name the products of a combustion reaction.

If you do any or all of these, you are relying on the combustion or burning of fossil fuels.

Chapter 3 discussed that fossil fuels are energy resources from the decayed remains of ancient plants and animals. (Chapter 8 discusses the formation of fossil fuels in more detail.)

In most cases, the energy stored in fossil fuels must be transformed into other forms of energy before it can be used. Combustion, or burning, is the most common way to transform this stored energy.

During a combustion reaction, a fossil fuel reacts rapidly with oxygen gas. The products of this combustion reaction are carbon dioxide gas ($CO_{2(g)}$) and water vapour ($H_2O_{(g)}$).

Like all exothermic reactions, the combustion of fossil fuels gives off energy. In a car engine, some of the chemical energy released is transformed into kinetic energy to turn the wheels of the car. If you feel a car hood after a long trip, you will know what most of the energy is given off as heat.

The following chemical equation describes the combustion of octane, a component of gasoline:

$$2C_8H_{18(l)} + 25O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(g)} + \text{energy}$$

The word equation for this reaction is:

octane + oxygen → carbon dioxide + water vapour + energy

In the following activity, you will investigate changes to the reactants and products in a common fossil fuel combustion reaction.

Find Out ACTIVITY

Evidence of a Combustion Reaction

When you light a candle, you observe fossil fuel combustion as the candle wax (made from fossil fuels) burns. In this activity, you will identify more evidence of fossil fuel combustion.

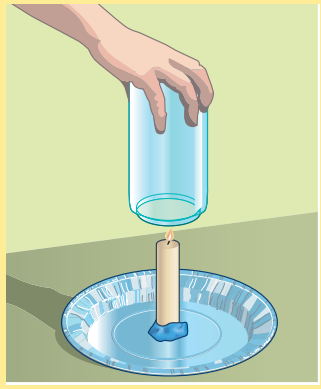
SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Safety Precautions

- Tie back long hair and secure any loose clothing.
- Clean up the work area and wash your hands thoroughly at the end of the activity.

What You Need

small ball of modelling clay
candle
pie plate with high sides
matches
glass jar
water
food colouring
ruler



What to Do

Part 1

1. Use the modelling clay to anchor the candle in the bottom of the pie plate.
2. Light the candle with a match.
3. Place the glass jar over top of the burning candle.
4. Carefully observe the candle as well as the glass jar. Record any evidence that a combustion reaction occurred in the glass jar.

Part 2

5. Remove the glass jar from over the candle.
6. Add enough coloured water to cover the bottom of the pie plate to a depth of 1 cm.
7. Light the candle.
8. Place the glass jar over top of the burning candle.
9. Make sure you observe the candle as well as the events that occur in the glass jar. Record any evidence that a combustion reaction occurred in the glass jar.

What Did You Discover?

1. Do the analysis provided by your teacher.

Incomplete Combustion

If fossil fuels do not burn completely, they undergo a chemical reaction called incomplete combustion. Incomplete combustion occurs when there is not enough oxygen available. For example, it may occur in a blocked chimney, an inefficient furnace, or a car engine running in a closed garage.

Complete combustion produces three products: carbon dioxide ($CO_{2(g)}$), water vapour ($H_2O_{(g)}$), and energy. Incomplete combustion produces five products: carbon monoxide ($CO_{(g)}$), carbon ($C_{(s)}$), carbon dioxide, water vapour, and energy.

Carbon monoxide is an odourless, colourless gas that is extremely poisonous. It combines with blood in the bloodstream to starve the body of oxygen, causing death. The carbon produced in an incomplete combustion reaction causes the black coating (soot) you see in fireplaces. How does this relate to your observations from the Find Out activity you just performed?

READING Check

List the five products of an incomplete combustion reaction.

Greenhouse Gases

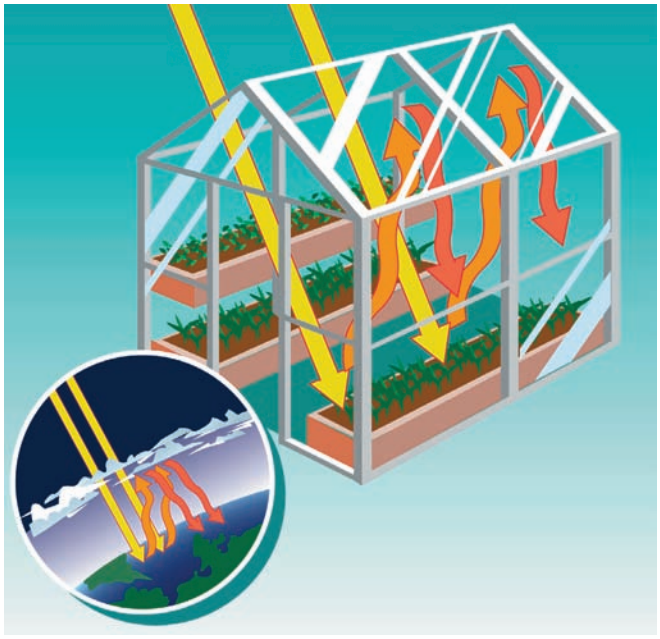


Figure 4.2 A greenhouse prevents heat from escaping into the atmosphere. Greenhouse gases work the same way to trap heat in Earth's atmosphere.

We use fossil fuels to heat homes, provide energy for industry, and generate electric energy. Our cars and trucks burn millions of litres of gasoline daily. All of these combustion reactions release millions of tonnes of carbon dioxide into the atmosphere. What effect does all this extra carbon dioxide have on Earth's atmosphere?

READING Check

Name some natural greenhouse gases.

Most scientists agree that carbon dioxide is important to life on Earth. All living creatures, including plants, produce it naturally. In fact, all living things produce carbon dioxide, water vapour, and methane. These are known as natural **greenhouse gases**.

Greenhouse gases trap heat in Earth's atmosphere and prevent heat from escaping into space. They also help to maintain the average global temperature of +15°C. Without them, the average global temperature would be much colder — about −18°C!

Global Climate Change

Throughout Earth's history, there have been intervals of warming and cooling. Scientists are concerned about the current long-term trend toward **global warming**. Accompanying this trend is a dramatic increase in extreme climatic events. Glaciers are melting. Sea levels are rising. Climate zones are shifting.

READING Check

In your own words, explain global climate change.

The real threat is the *rate* at which **climate change** is occurring. Climates are changing much faster than in Earth's past. Scientists point out that many species of organisms will not be able to adapt to such fast changes. These organisms may become extinct.

Some people believe that climate change is a natural phenomenon. They note that Earth has gone through many ice ages with shorter periods of warming between the ice ages. The Earth and its species will adjust.

In the following investigation, you will consider both sides of the global warming issue.

INVESTIGATION 4–A

SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Glacier high above Peru in the Andes Mountains, 1978

The same glacier, 2000

Climate Change: What is Your Position?

Think About It

There is abundant evidence that the global climate has warmed significantly during the last century. Scientists point out that this is due to the increase of two greenhouse gases: carbon dioxide and methane.

- The burning of fossil fuels such as coal and gasoline has released tremendous amounts of carbon dioxide.
- Human activities such as burning vegetation, landfilling garbage, growing rice in large paddies, and keeping large amounts of cattle together in feedlots release large quantities of methane.

The level of these and other greenhouse gases released by human activities appears to be causing the current rapid global warming.

The Earth has experienced natural variations in climate throughout its history. In fact, the greenhouse effect maintains the temperature of the Earth at a level suitable for life to exist.

Natural climate changes occur over a relatively long period of time. Because the change is gradual, organisms adapt to the new temperature and precipitation patterns.

Today, many scientists are concerned about the rate of change. Global temperatures are changing much faster than in the past. Will species have enough time to adapt to the new climate?

Some skeptics argue that there is nothing to worry about. Warmer temperatures will make Earth more hospitable for humans and other organisms. They also question the reliability of the climate models that scientists use to make predictions about climate change. What do you think?

What to Do

1. Work in teams of three or four students.
2. Each member of the group should use an approved search engine to locate:
   - one web site that *supports* the scientific viewpoint that human activities are directly related to climate change; and
   - one web site that *refutes* the scientific viewpoint that human activities are directly related to climate change.
3. Evaluate and summarize the information found on each web site.

Analyze

1. As a group, compare the information that you found supporting and refuting the scientific view that human activity is responsible for the rapid increase in global temperatures. Use a chart or other tool to organize the data that you collect.

Air Pollution

Carbon dioxide is not the only chemical substance that human activities add to the air. Many other chemicals in the air cause harm to living things or the environment. These chemicals are called **pollutants**.

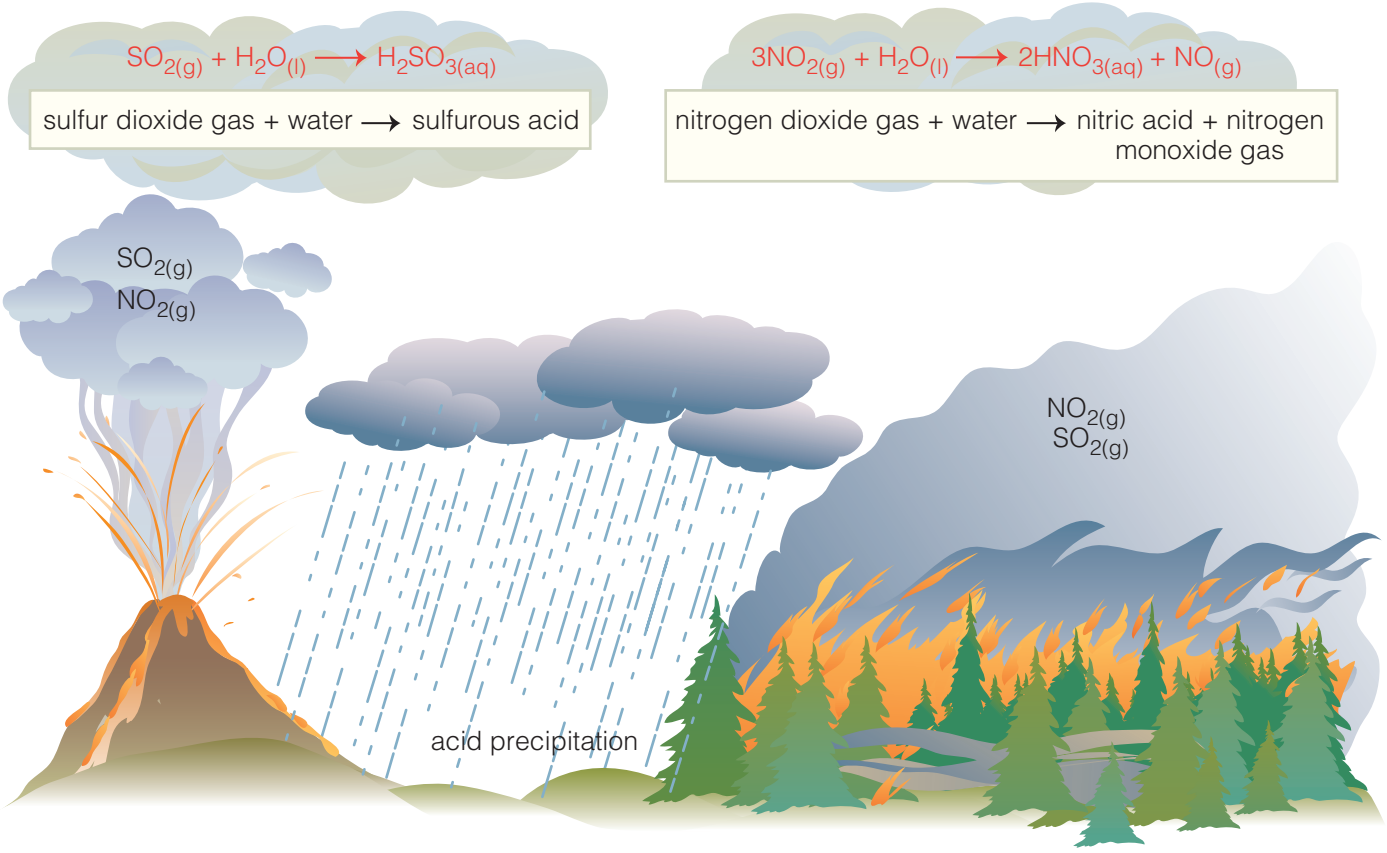
READING Check

In your own words, explain how acid deposition is produced.

Air pollutants can cause problems such as asthma, headaches, and irritation of the eyes, nose, and throat. They can also aggravate heart and lung conditions.

Even worse, air pollutants can combine with each other to produce **acid precipitation** or rainwater that has become more acidic. The more accurate term for this phenomenon is **acid deposition** since dry matter, as well as precipitation, causes acids. Study Figure 4.3 and identify the different sources of pollutants that contribute to acid deposition. Notice the chemical reactions involved.

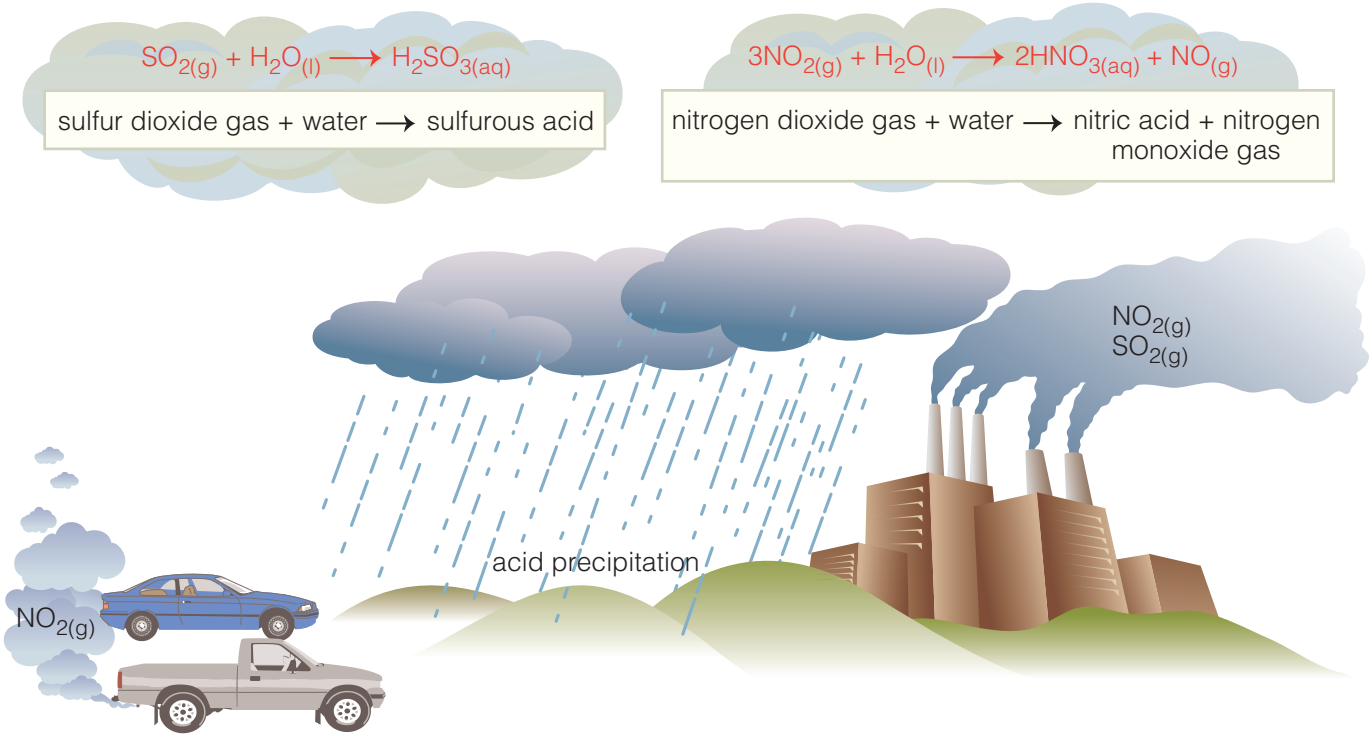
Figure 4.3A Natural Formation of Acid Deposition.


$SO_{2(g)} + H_2O_{(l)} \longrightarrow H_2SO_{3(aq)}$
sulfur dioxide gas + water ⟶ sulfurous acid
$3NO_{2(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(aq)} + NO_{(g)}$
nitrogen dioxide gas + water ⟶ nitric acid + nitrogen monoxide gas
$SO_{2(g)}$
$NO_{2(g)}$
$NO_{2(g)}$
$SO_{2(g)}$
acid precipitation

When volcanoes erupt, they release carbon dioxide and water vapour. They also release **sulfur dioxide** ($SO_{2(g)}$) and **nitrous oxides** ($NO_{x(g)}$) into the atmosphere. These gases mix with water vapour in the clouds to form diluted sulfurous and nitric acids.

Forest fires release carbon dioxide and water vapour. The burning of wood also releases nitrogen dioxide ($NO_{2(g)}$) and some sulfur dioxide ($SO_{2(g)}$) into the atmosphere. Both of these gases react with rainwater to make acid deposition.

Figure 4.3B Human Contribution to Acid Deposition
Like air pollutants, acid deposition comes from both natural sources and human activities. Study the illustrations here and on page 64 to identify both natural and human-made causes of acid deposition.


$SO_{2(g)} + H_2O_{(l)} \longrightarrow H_2SO_{3(aq)}$
sulfur dioxide gas + water ⟶ sulfurous acid
$3NO_{2(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(aq)} + NO_{(g)}$
nitrogen dioxide gas + water ⟶ nitric acid + nitrogen monoxide gas
$NO_{2(g)}$
$SO_{2(g)}$
acid precipitation
$NO_{2(g)}$

In a similar way, nitrogen oxides emitted from car exhaust react with rainwater to form nitric acid.

Industrial smokestacks release sulfur dioxide and nitrogen oxides, which react with rainwater to make acid deposition.

Disc CONNECT

For more information about acid precipitation and other forms of acid deposition, load the student CD-ROM onto your computer. Launch the **Acid Deposition** applet and follow the instructions.

Check Your Understanding

1. List three natural greenhouse gases.
2. Describe three negative effects of global climate change.
3. What are the major contributors to acid deposition?
4. Name two gas emissions that are linked to acid deposition.

Key Terms

- greenhouse gases
- global warming
- climate change
- pollutants
- acid precipitation
- acid deposition
- sulfur dioxide ($SO_{2(g)}$)
- nitrous oxides ($NO_{x(g)}$)

4.2 Acid–Base Reactions

READING Check

Explain a neutralization reaction that occurs in your digestive system.

Chapter 3 discussed what happens when an acid and a base are combined. This produces a neutralization reaction. During this neutralization reaction, the acid and base react together to form two new chemical compounds: a salt and water.

Neutralization reactions do not just happen in labs. They also happen in your body. Study Figure 4.4 — read both the caption and labels — to see how your digestive system uses neutralization reactions.

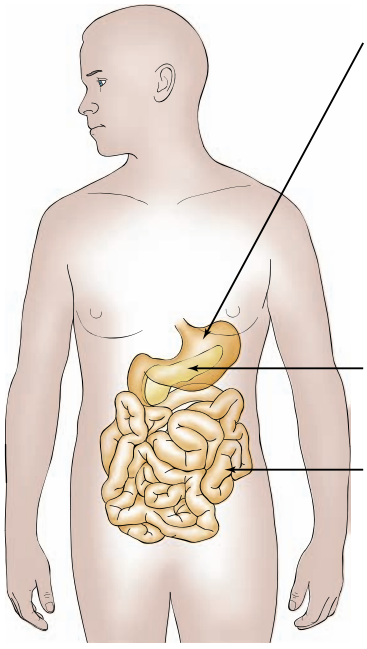

stomach
Cells in the stomach release hydrochloric acid to help digest food. Hydrochloric acid is so strong that it could literally eat away the lining of your digestive tract. In order to prevent this, other cells in your stomach continually release mucous. Mucous contains a base that neutralizes any acid that comes into contact with the wall of the stomach. This explains why the stomach does not digest itself.
pancreas
The pancreas produces sodium bicarbonate solution that is dumped into the small intestine.
small intestine
After leaving your stomach, the acidic food enters the small intestine. Sodium bicarbonate from the pancreas and from cells in the small intestine neutralizes the acid.

Figure 4.4 The following equations show what happens during the neutralization reaction in your digestive system. What product does this reaction produce?

$$HCl_{(aq)} + NaHCO_{3(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

hydrochloric acid + sodium bicarbonate → sodium chloride + water + carbon dioxide

Figure 4.5 Calcium carbonate is released into a lake affected by acid precipitation. This neutralizes the lake water. Such liming is not a permanent solution to the effects of acid precipitation. Why do you think this is so?

Acids and Bases in the Environment

Natural limestone ($CaCo_{3(s)}$) is a base used by industry. This base is also used to neutralize lakes that have been acidified by acid precipitation. This technique is called **liming**.

During liming, calcium carbonate ($CaCO_{3(s)}$) is added to the waters of an acid lake. The calcium carbonate neutralizes the acidic water, thus raising the pH of the lake water.

Study Figure 4.6 (on page 67) to see what happens to the pH of acidic water during the neutralization process. Also study the equations showing this chemical reaction.

READING Check

Explain the benefit of adding lime to lakes.

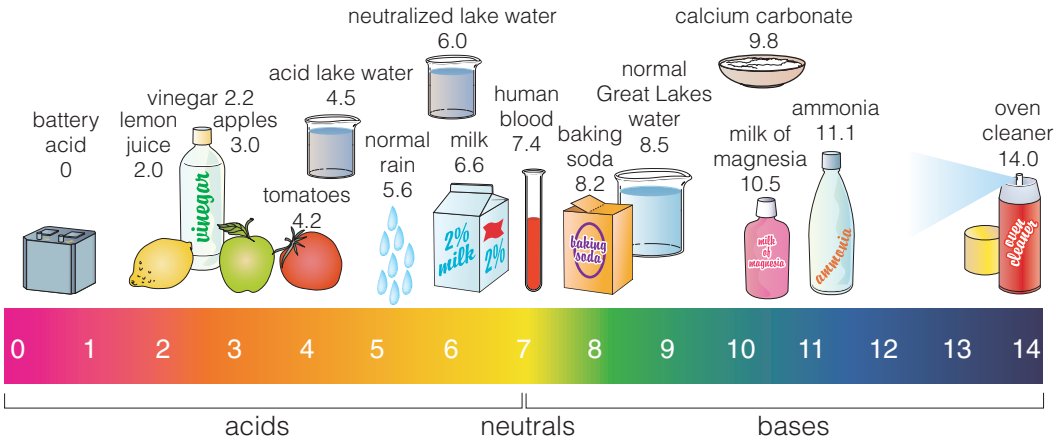


Figure 4.6 The pH scale tells you how acidic or basic a substance is. Identify the pH levels of an acid lake, calcium carbonate, and a neutralized lake. The liming process is represented by the following word and chemical equations:

sulfuric acid + solid calcium carbonate → solid calcium sulfate + carbon dioxide gas + water

$H_2SO_{4(aq)} + CaCO_{3(s)} \rightarrow CaSO_{4(s)} + CO_{2(g)} + H_2O_{(l)}$

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

Use the Internet to investigate how liming raises the pH of acidified lakes. Go to the above web site, then to Internet Connects, Unit A, Chapter 4, and then to Liming Acid Lakes.

Try This!

Add drops of vinegar to 100 mL of water until a test with universal pH indicator paper shows the solution has a pH of about 4.5. Slowly add lime (calcium carbonate) to the solution, testing with universal pH indicator until a pH of 6.0 is reached. What reaction did you just create?

Reducing Emissions

A better way to reduce acid deposition is to prevent it from forming. In Figure 4.3 on page 64–65, you learned that sulfur and nitrogen oxides are responsible for the high levels of acid deposition. Sulfur dioxide is a major by-product of industrial processes. It is also a product in the combustion of fossil fuels like natural gas.

READING Check

Name two sources of sulfur dioxide emissions.

One way to reduce sulfur emissions is to remove the sulfur from the fuel before the fuel is burned. Figure 4.7 shows one place in Alberta where this is done. Turn the page to learn *how* it is done.

DidYouKnow?

The coal mined in Alberta is valued for its low sulfur content.

Figure 4.7 At gas plants such as this one in Waterton, Alberta, hydrogen sulfide has been removed from natural gas. The by-product of this chemical reaction is sulfur.

Removing Sulfur from Fuel

Most scientists agree that using sweet natural gas is one way to reduce emissions that produce acid precipitation. You may have noticed large yellow piles of sulfur at some natural gas plants in Alberta. This sulfur has been removed from sour natural gas before it is sent to consumers. Since sulfur emissions are one of the main causes of acid precipitation, removing sulfur from the fuel *before* burning it will reduce acid precipitation.

READING Check

Explain why sulfur is removed from natural gas.

Sulfur Scrubbing

The coal produced in some areas of the country contains sulfur. When this coal is burned, the sulfurous emissions can return to Earth as acid precipitation. To help prevent this, a device known as a **scrubber** is installed on the smokestacks of many industrial plants that burn coal.

READING Check

Explain in your own words how sulfur scrubbing works.

Scrubbing is a chemical and physical process that removes sulfur compounds formed during the combustion of coal. Look at Figure 4.8 to see how this is done. Scrubbers remove the sulfur from the smokestack before it reaches the atmosphere. Study the equations in the figure and trace what happens to the coal, limestone, and air that enter the furnace.

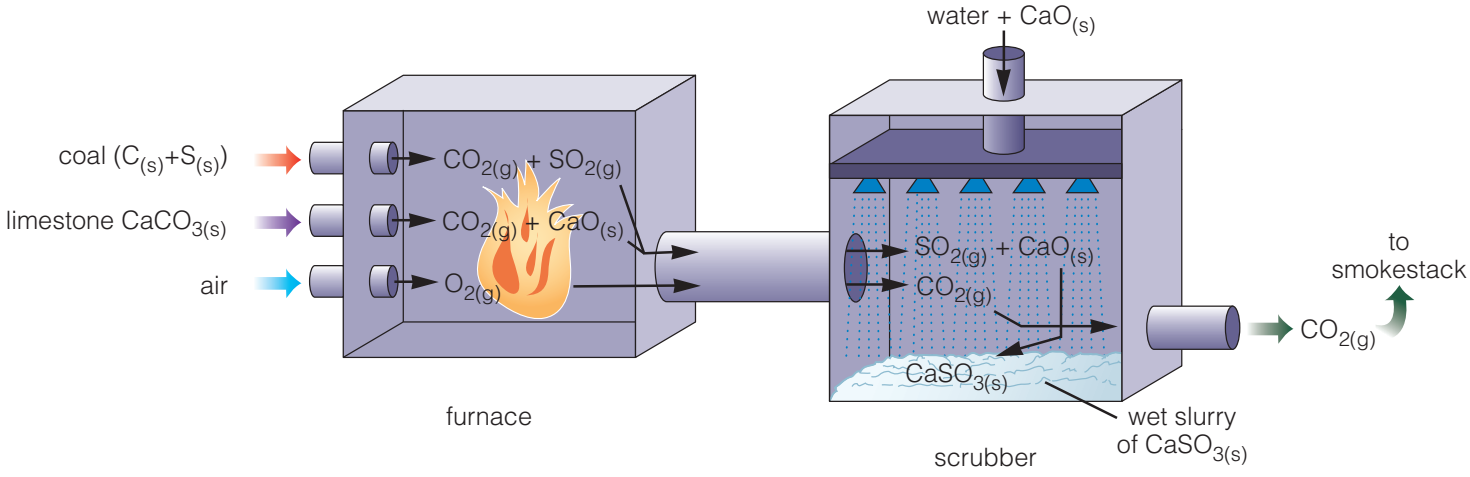


Figure 4.8 In the final stages of scrubbing, calcium oxide ($CaO_{(s)}$) is injected. It reacts with sulfur dioxide gas ($SO_{2(g)}$) to form a wet slurry of calcium sulfite ($CaSO_{3(s)}$). Calcium sulfite forms the sludge that is washed away with water. Using this method, scrubbers can remove more than 95 percent of the sulfur dioxide from smokestack emissions.

Key Terms

liming
scrubber

Check Your Understanding

1. Write out the general chemical equation for a neutralization chemical reaction.
2. Describe how driving a car contributes to the problem of acid precipitation.
3. Explain how liming can raise the pH of a lake affected by acid precipitation.
4. Why is it important to remove sulfur from coal and natural gas before they are burned?

4.3 Corrosion of Iron

Figure 4.9 Iron and steel will rust when exposed to oxygen and moisture.

Figure 4.10 Rusting is an example of a simple composition chemical reaction. Check the information on page 44 in Chapter 3 to review this reaction type.

Corrosion refers to any process that chemically breaks down or degrades metal. The best-known case of corrosion is the **rusting** of iron. Most metals will rust, but the corrosion of iron and steel is a serious problem because these metals are widely used. As rust flakes off an iron structure, more metal is exposed to the environment. The structure is weakened over time, as more and more metal is exposed.

Have you ever left a metal tool or toy outside and found that it rusted and broke? If so, you might think rust is a decomposition reaction. In fact, rusting is a simple composition reaction.

Examine the chemical reaction for the corrosion of iron, shown below. Iron is reacting with oxygen to produce iron oxide, which is commonly called rust. Although it is not included in this chemical equation, water is also required for rusting to occur.

$$4Fe_{(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)}$$

solid iron + oxygen gas → iron (III) oxide

Scientists and engineers are concerned about the corrosion of steel. Unless rusting is prevented, it will weaken an iron or steel structure. The rusting of the steel used to reinforce concrete in bridges and buildings can cause these structures to fail and collapse. Repairing or replacing these structures costs millions of dollars.

READING Check

Explain how rusting is a simple composition reaction. What are the reactants? What is the product?

DidYouKnow?

Gold is one metal that does not corrode. This is one reason why many gold objects have survived for thousands of years.

Try This!

To see how acid deposition might accelerate the corrosion and destruction of building materials, place an egg in a small beaker. Add enough vinegar to cover half the egg. Leave the beaker undisturbed for a few days and observe the effects of the acid.

CONDUCT AN

INVESTIGATION 4–B

SKILL CHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

Corrosion of Iron

In this investigation you will model the factors that cause the corrosion (or rusting) of steel wool, which is made mainly from iron.

Problem

What factors cause the corrosion (rusting) of iron?

Prediction

What environmental factor do you think is responsible for the rusting of iron?

Safety Precautions

- Read the procedure carefully before starting this investigation.
- Clean up the work area and wash your hands thoroughly at the end of the investigation.

Apparatus

3 test tubes of equal size and small enough to fit into a graduated cylinder

3 graduated cylinders (100 mL)

3 test tube clamps and stands

electronic balance

small beaker

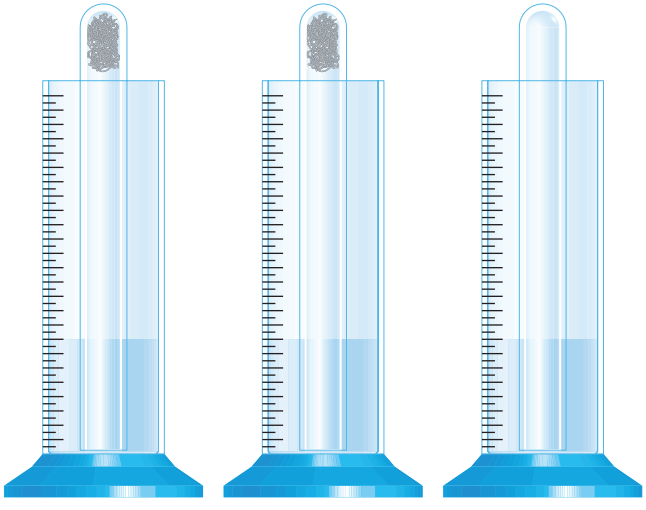
Materials

1 g steel wool

water

Procedure

1. Obtain 1 g steel wool and divide it into two equal pieces. Roll the steel wool into tiny spheres that will fit into the test tubes but will not fall out if you turn the test tubes upside down.
2. Add some tap water to the small beaker and soak one of the steel wool spheres for about five minutes. Leave the other sphere of steel wool dry.
3. Squeeze the excess water from the first sphere and place this piece of steel wool in the bottom of one test tube.
4. Place the dry steel wool in the bottom of the second test tube.
5. Leave the third test tube empty.
6. Add approximately 40 mL of water to each of the three graduated cylinders.
7. Set up the three test tubes as shown in the figure. Remember, one test tube will be empty.



Make a table like the one shown here in your notebook. Use it to record the volume of the water level in each test tube.

	Water Level in the test tube with the wet steel wool (mL)	Water Level in the test tube with the dry steel wool (mL)	Water Level in the control (empty) test tube (mL)
Start			
After 24 hours			
change in water level			

Leave the apparatus set up for at least 24 hours.

Record the level of water in each test tube after 24 hours.

Calculate and record the change in the water level in each test tube.

Try This!

The rusting of steel is similar to the combustion of fossil fuels. Both reactions require oxygen. Remove one thread of steel wool. Use tongs to hold the steel wool — do not use your fingers! Hold the thread of steel wool in the flame of a burning candle. What happens to the steel wool?

Before doing this activity, list the safety equipment needed. Get your teacher's approval, and use the necessary safety equipment.

Analyze

1. Describe what happened to the amount of water in the test tube that had:
   - **(a)** the wet steel wool
   - **(b)** the dry steel wool
   - **(c)** the control
2. If rusting requires oxygen, oxygen would be used up in the chemical reaction. Water would move into the test tube to replace the oxygen. Which test tubes showed that oxygen was consumed in this reaction?
3. Explain which test tube demonstrated that water speeds up the process of rusting.

Conclude and Apply

4. Did the evidence you gathered support or reject your original prediction? Explain your answer.
5. Using the equation on page 69 as a guide, write out the chemical equation and the word equation for the rusting of steel.
6. How do you think you could prevent the rusting of metal such as steel wool?

Check Your Understanding

1. Write out the word and the chemical equations for the corrosion of iron.
2. List the two environmental factors that must be present in order for iron to rust.
3. Why is the combustion of steel wool similar to the corrosion of steel wool?

Key Terms

corrosion
rusting

4.4 Solving the Problem of Corrosion

Figure 4.11 When oxygen and water contact the surface, metals such as iron and steel will rust.

Figure 4.12 Paint can protect steel from corrosion. This bridge has been cleaned with high-pressure jets of water to remove loose paint, rust, and other loose debris. The cleaned surface was then given a fresh coat of protective paint.

Have you ever noticed that metal parts of a car that have been damaged in a collision are more susceptible to rusting? Why would some metal parts of the car rust while others remain rust free? The answer is in the way metals are protected.

Painting — One way to protect metals is to give them a protective coating of paint. Painting over the metal prevents oxygen and water from reaching the surface of the metal. This explains why steel beams used in office buildings or on bridges are often painted with red paint.

Painting, however, may not be the best way to permanently protect iron or steel. Once the paint chips off, water and oxygen are free to attack the steel, and rust blisters grow rapidly.

Galvanizing — Another way to protect steel or iron is to use a process called **galvanization**. Galvanization is the process of applying a zinc coating to iron or steel. This involves immersing the metal in a bath containing molten zinc. This process coats the metal with a layer of zinc that provides a protective barrier between the metal and the environment. The galvanized coating adheres to the base metal and resists chipping and cracking. In fact, the zinc coating actually becomes part of the surface of the steel.

Some galvanized nails also have a polymer coating to increase the protection. Chapter 1 discusses how polymers can be developed for special needs. In this case, polymers help protect metal from rusting.

Sacrificial Metal — A third method of protecting iron involves the use of a **sacrificial metal**. If you could look closely at an underground oil pipeline, you would notice bars or ingots of a second metal, such as magnesium, buried with the pipeline. The magnesium will corrode but the pipeline will not. In this case the magnesium is sacrificed in order to protect the pipeline.

The equation for this is:

$$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$$

It is much easier and cheaper to replace the bars of magnesium than it is to repair a ruptured pipeline.

READING Check

Describe three methods of protecting metals from corrosion.

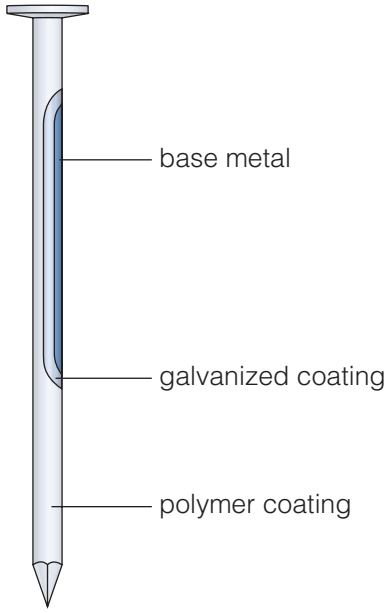


Figure 4.13 Galvanized nails resist rust for many years.

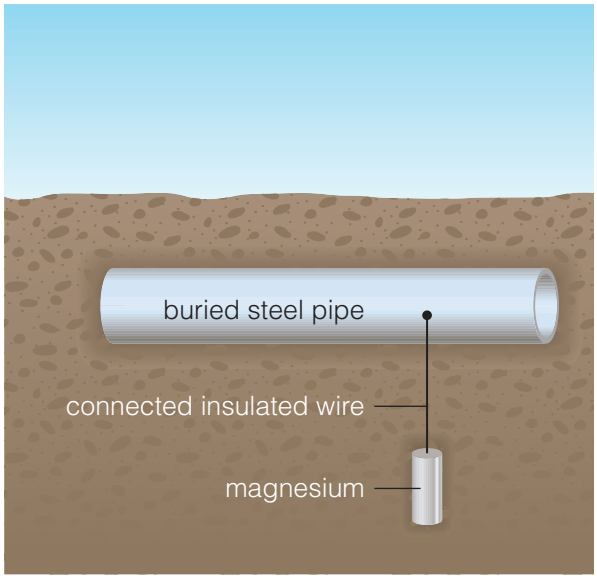


Figure 4.14 Magnesium ($Mg_{(s)}$) is sacrificed to protect steel pipelines that contain iron ($Fe_{(s)}$). Magnesium, zinc, and aluminum are commonly used as sacrificial metals.

Check Your Understanding

1. Explain why the chemical reaction for the rusting of steel is similar to the chemical reaction for the combustion of a fossil fuel.
2. How does painting a steel beam protect it from rusting?
3. How does dipping nails into molten zinc help prevent them from corroding?

Key Terms

galvanization
sacrificial metal

CHAPTER

4 Review

Key Terms

greenhouse gases
global warming
climate change
pollutants
acid precipitation
acid deposition
sulfur dioxide ($SO_{2(g)}$)
nitrous oxides ($NO_{x(g)}$)
liming
scrubber
corrosion
rusting
galvanization
sacrificial metal

Reviewing Key Terms

If you need to review, the section numbers show where these terms were introduced.

1. All of the following statements are false. As you rewrite each statement in your notebook, change one or two words to make it true.

(a) The two reactants of the combustion of gasoline are carbon dioxide gas and water vapour. (4.1)

(b) Combustion reactions release energy and are classified as endothermic. (4.1)

(c) The release of excess carbon dioxide gas into the atmosphere is thought to be associated with acid precipitation. (4.1)

(d) Pollutants released into the atmosphere do not usually bother people with asthma and other medical conditions. (4.1)

(e) The pH of normal rainwater is 4.0. (4.2)

(f) Sulfurous acid is associated with global warming (4.1)

(g) The products of a neutralization reaction are an acid and a base. (4.2)

(h) A scrubber is a technology that helps reduce the gases associated with global warming. (4.2)

(i) The brown material flaking off the side of an old car is a fossil fuel. (4.3)

(j) Iron nails can be protected from rusting by dipping them in an acid. (4.4)

(k) Global warming concerns many scientists because many species may not be able to adapt at the rate temperatures are currently changing.

(l) Acid precipitation includes both dry matter and precipitation.

Understanding Key Ideas

Section numbers are provided if you need to review.

2. Write out the word and chemical equations for one of the combustion reactions described in the first section of this chapter. (4.1)

3. Use both word and chemical equations to describe how sulfur dioxide gas ($SO_{2(g)}$) is turned into an acid in the atmosphere. (4.1)

4. List three health problems that may be aggravated by air pollutants. (4.1)

5. Identify three naturally occurring greenhouse gases. (4.1)

6. Why do some people take antacid tablets when they have heartburn? (4.2)

7. Why is lime added to lakes in some parts of eastern Canada? (4.2)

8. How is a combustion reaction similar to the corrosion of iron? (4.3)

9. Why is the steel used in a building coated with red paint? (4.4)

Developing Skills

10. Look at the photograph of the burning candle. What evidence is there that this is a combustion reaction? (4.1)

11. Describe the procedure that you could follow to determine if a new coating will prevent the corrosion of a iron nail. (4.4)

Problem Solving/Applying

12. Identify one technology that can be used to reduce the amount of sulfur dioxide entering the atmosphere. Use chemical equations and word equations to explain how this technology works. (4.1)

13. An unknown tablet was found to contain the chemical aluminum carbonate. When dissolved in distilled water, the pH of the mixture was approximately 8.0. Describe a simple investigation you could do to determine if this compound would make a good ingredient in an antacid tablet. (4.2)

14. Describe the connection between the greenhouse gas carbon dioxide and concerns about global warming. (4.1)

Critical Thinking

15. It is cheaper to paint a car than it is to produce the galvanized steel needed to make a new car. When you are shopping for a new car, you have a choice between a car made with galvanized steel and one made with ordinary steel. The car made with galvanized steel costs $1000.00 more. The manufacturer's warrantee for the rusting lasts nearly twice as long for the car made with galvanized steel. Would you spend the extra $1000.00 to purchase the car made with galvanized steel? Why or why not? (4.4)

Pause & Reflect

1. The chemical industry and the combustion of fossil fuels have provided our society with many of the benefits we enjoy today. However, these same products and processes have created many environmental concerns. What changes to your lifestyle would you be willing to make to reduce the environmental damage caused by these products or the chemical reactions associated with these materials?

2. Go back to the beginning of the chapter (on page 58). Check your answers to the Getting Ready questions. How has your thinking changed? How would you change your answers now that you have investigated the concepts in this chapter?

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

An *Issue* to Analyze

A PUBLIC FORUM

"Not in My Backyard"

Throughout this unit you have learned to identify and classify chemical reactions that occur all around you. You have learned how chemical changes occur, and how chemistry is used to improve your standard of living. You now understand the chemistry behind many common industrial processes. In this activity you will use what you have learned to evaluate how chemical change affects the world around you.

Think About It

Ammonia ($NH_{3(g)}$) is a colourless, strong-smelling gas at room temperature. Ammonia can be fatal if inhaled. One of its compounds, ammonium nitrate ($NH_4NO_{3(s)}$), is used to make fertilizers and explosives.

Commercially, ammonia is produced by reacting nitrogen with hydrogen at high temperatures and pressures.

The following equations show this chemical reaction:

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

nitrogen gas + hydrogen gas → ammonia gas

Background

In this activity you will role-play what might happen in a small rural community where the following events are planned.

- The president of a new company wants to build a chemical plant near the community. This plant will process ammonia to produce ammonium nitrate for fertilizer and explosives.
- The company plans to purchase land near the edge of town. The property they want is close to a marsh that is a favourite resting place for migrating ducks.

- The company expects to employ up to 150 local residents, mostly in manufacturing jobs. There will also be openings for engineers and chemists. Local farmers expect to benefit from reduced fertilizer costs.

Many townspeople are happy about the company's plans. Some expect to get jobs in the plant. Others hope the plant will boost the local economy. This would mean their children may be able to find jobs locally when they finish school. Local business owners look to the new plant as a potential customer.

Some people, however, are concerned about the risks to the environment and human health. In particular, they are worried about the effects of fumes, gaseous emissions, potential spills, and explosions.

The company president is aware of these concerns and has assured the mayor that the plant will be equipped with pollution control technologies. As well, the president claims that every effort will be made to minimize spills and leaks.

The company's proposal includes an action plan that explains what the company will do if a spill or leak occurs. This action plan will be delivered to every home.

During this activity, you will participate in a town hall meeting to discuss the various concerns about the company's plans. The meeting will be chaired by the town's mayor, who wants to hear what local people think about the issues before making a decision. During this town meeting, representatives from a number of special interest groups will make presentations. Community members will be invited to ask questions and voice their concerns.

The following people will speak at the meeting:

Representatives of Special Interest Groups

- an area farmer
- a member of an environmental advocacy group
- a chemist who lives in the community
- a town resident who has asthma, a respiratory illness

Company Representatives

- the president of the company
- the architect who will design the plant
- a chemical engineer

What to Do

1. Briefly outline what you think each person's point of view will be before the meeting takes place. This will help to prepare you for the forum.

2. Your teacher will give your group the role of one of the people listed above. As a group,
   - discuss the issue,
   - gather information about how such a plant might affect a rural community, and
   - formulate a point of view for the person your group is representing.

3. When the forum takes place, your group will have three minutes to state your case. The other members of the class will represent community residents. They will be invited to ask questions and state their concerns.

4. As a class, your task is to assess the presentations made at the meeting and evaluate the possible risks of the new chemical company. You will make a recommendation to the mayor about whether to accept or reject the company's application.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

Use the Internet to gather information about how such a plant might affect a rural community. Go to the above web site, then to Internet Connects, Unit A Project, and then to "Not in My Backyard".